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Treatment of High Strength Meatpacking Plant Wastewater by Land Application

Texas Univ at El Paso Dept of Civil Engineering

Prepared for

Robert S Kerr Environmental Research Lab, Ada, Okla Wastewater Management Branch

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Using a raw wastewater which had a COD of 9,400 mg/l, the results showed that both types of land application systems performed well with respect to COD removal, with an efficiency of 99% at a 10 cm/week rate for the infiltration system and 84% at a 12.5 cm/week rate for overland flow. Both systems were less efficient with respect to nitrogen removal, averaging 58% and 44% for the infiltration and overland systems respectively. Two warm season grasses (Bermuda NK-37 and Blue Panicum) and two cool season grasses (Kentucky-31 Tall Fescue and Jose Wheatgrass) were shown to grow very well when irrigated with the meatpacking plant wastewater.

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TREATMENT OF HIGH STRENGTH MEATPACKING PLANT WASTEWATER BY LAND APPLICATION

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ABSTRACT

The purpose of this study was to determine the treatability of high strength meatpacking plant wastewater by land application. Both infiltration and overland flow type systems were studied at various hydraulic and organic loading rates. In addition to characterization of the raw and treated wastewater, laboratory and field studies were conducted in order to find one or more grasses which would be suitable for soil cover. Related investigations were also made regarding aerosol drift during high pressure and low pressure distribution, wastewater characterization from unit processes within the meatpacking plant, and chemical treatability of unit wastes using ferric chloride.

Using a raw wastewater which had a COD of 9,400 mg/l, the results showed that both types of land application systems performed well with respect to COD removal, with an efficiency of 99% at a 10 cm/week rate for the infiltration system and 84% at a 12.5 cm/week rate for overland flow. Both systems were less efficient with respect to nitrogen removal, averaging 58% and 44% for the infiltration and overland systems respectively. Two warm season grasses (Bermuda NK-37 and Blue Panicum) and two cool season grasses (Kentucky-31 Tall Fescue and Jose Wheatgrass) were shown to grow very well when irrigated with the meatpacking plant wastewater.

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SECTION I
CONCLUSIONS

* Meatpacking plant wastewater is amenable to treatment by land application using either infiltration or overland flow systems.
* Several types of grasses grow well when irrigated with meatpacking plant wastewater, including Bermuda NK-37, Kentucky-31 Tall Fescue, Jose Wheatgrass, and Blue Panicum.
* High concentrations of grease can be removed from meatpacking plant wastewater by infiltration-type land application systems.
* Low pressure wastewater distribution systems reduce aerosol drift considerably compared to high-pressure systems.
* Overall treatment efficiency could be improved by increasing the length of the overland-flow system beyond 62 meters for strong meatpacking plant wastewater.
* The high nitrogen concentration present in most meatpacking plant wastewater minimizes the possibility of achieving high percentage nitrogen removals without extremely close control of the treatment system.
* Several factors which are peculiar to meatpacking wastewater must be taken into consideration when planning and designing land application systems.
* The southwestern United States, with its arid climate, mild winters, and vast available land areas, presents ideal conditions for land application treatment systems.

SECTION II
RECOMMENDATIONS

* Full-scale demonstrations should be conducted for both infiltration and overland-flow systems using medium and low strength meatpacking plant wastewaters.

* Because of the high concentration of nitrogen in meatpacking plant effluents, more studies should be conducted to determine the fate of the nitrogen compounds originally present.

* The feasibility of segregation or separate treatment of high strength wastes generated within the packing plants should be investigated.

* Other treatment processes should be studied in combination with land application in order to achieve the most efficient overall treatment at the lowest equivalent uniform annual cost.

* More research should be conducted on a pilot scale for modelling the overland flow treatment process in order to maximize efficient land usage and minimize overall costs.

* Additional low cost, low pressure, distribution systems, i.e., less than 1.4 kgs/sq cm (20 psi) should be developed for infiltration type treatment systems.

* The extent of danger presented by pathogenic bacteria which may be present in the wastewater should be investigated.

* The palatability and wholesomeness to the animals of the grasses grown in the treatment system should be studied so that the grasses can be sold, thereby generating revenues which reduce the cost of the treatment systems.

SECTION III
INTRODUCTION

The application of municipal and industrial wastewaters to land for treatment and/or disposal is not new. A textbook on wastewater treatment which was published in 1903 contained complete chapters on sewage irrigation and sewage farming (1). The land application method of wastewater treatment has been demonstrated not only in the United States, but in many foreign countries as well. Liquid wastes with a wide spectrum of physical and chemical characteristics have been treated successfully by soil application, including municipal sewage, cannery wastes, pulp and paper mill wastes, dairy wastes, vegetable and food processing wastes, wood distillation wastes, poultry wastes, and many others (2,3).

With the constant annual increase in per capita consumption of beef and meat products, the need for technological advances in the treatment of meat packing wastes has never been greater.

In 1967, the potential daily Biochemical Oxygen Demand (BOD) from the slaughterhouse and meat packing industry was estimated at 2.17 million pounds or a population equivalent of 13 million people (4). The U.S. Department of Agriculture places the meatpacking industry second to only the Pulp and Paper Industry in terms of potential five day BOD pollution. In the food and kindred products industry, meatpacking ranks first in daily pollutional discharge.

Interest in the land application method of wastewater treatment for meatpacking plant wastes has been stimulated by recent federal regulations requiring a greater degree of wastewater treatment. Of particular importance in this regard is the increased emphasis that is being placed on residual carbon, nitrogen and phosphorous removal. Some land application systems have effectively removed almost all of the carbon and phosphorous and, under controlled operating conditions, a large percentage of the nitrogen. In addition to the high degree of waste treatment

which is achieved, of course, some of the valuable plant nutrients are recovered in the process. The purpose of this report is to present the experiences gained during pilot scale treatment of meatpacking plant wastewater by land application.

SECTION IV
BACKGROUND

WEATHER

Although a high degree of treatment can be expected for most climatic and soil conditions with a properly designed and operated system, the arid southwest is particularly adapted to wastewater treatment by soil application. The climate in the El Paso area is arid subtropical, characterized by an abundance of sunshine throughout the year, high summer temperatures, low humidity, scanty rainfall, and a cool winter season. Rainfall throughout the year is light, with an annual mean of 20 cms. Dry periods of several months' duration without appreciable amounts of rainfall are not uncommon, with more than half of the precipitation occurring in the summer months from brief, but at times heavy thunderstorms (5).

Daytime summer temperatures are high, frequently above 90°F and occasionally above 100°F, but summer nights are usually cool, with minimum temperatures in the sixties. Winter daytime temperatures are mild, rising to 55 to 60°F on the average. At night they drop to the twenties and thirties and only rarely go below 15°F. The arid climate causes a rather high evaporation rate, with a class A pan evaporation rate of 267 cms per year and a mean annual lake evaporation rate of 183 cms.

STUDY SITE DATA

The Peyton slaughterhouse-meatpacking plant is located in the southeast El Paso Valley in a predominantly agricultural area. The company owns 9 hectares of land, with the plant and parking lot occupying 1 hectare and the remaining 8 planted in river-irrigated alfalfa at the time this project was begun. During the time this study was conducted, the company slaughtered about 425 head of cattle per day and imported about 400 head of dressed swine per day. At the present time, however, the company has a 16-hour kill which nearly doubles the previous daily processing rate. A variety of meat products are made and packaged at the plant, including

bacon, hot dogs, balony, hams and full lines of sausage and smoked meat.

In spite of the many by-product recovery processes employed in the plant, the wastewater discharge is very strong and quite typical of wastes generated by slaughterhouse-meat packing plants (6), as will be described in the wastewater characterization section below.

SOIL TYPE

The soil surrounding the packing plant has been classified by the U.S. Soil Conservation Service as follows:

Soil Depth, cm	% Clay	% Silt	% Sand	USDA Texture
0 - 20	22.6	25.7	51.7	Sandy clay loam
20 - 180 +	2.9	6.2	90.0	Fine sand

Although samples were not taken below 3 meters, the U.S. Soil Conservation Service indicated that unless thin layers of clay intrusions were present, the soil from 3 meters down would probably fit the fine sand classification.

GROUND WATER

The ground water level in the vicinity of the packing plant is located at about 2.5 meters from the ground surface. This relatively high TDS groundwater is used to supplement river water from the Rio Grande for irrigation during periods of low-water allotments. The values shown in Table 2 are representative of the average chemical composition of the ground water (7):

Table 2 - Ground Water Characteristics

Parameter	Concentration
pH	7.6
total solids	3,200 mg/l
Cl	720 mg/l
SO_4	1,080 mg/l
HCO_3	452 mg/l
Hardness	705 mg/l
Ca	187 mg/l

Although the quality of the shallow ground water varies slightly from one area to the next as well as with time, the general quality of the water is poor for commercial uses.

SECTION V
PROCEDURES AND DESIGN

This section is divided into two main parts, with laboratory procedures comprising the first part and field procedures and design the second. Appropriate subheadings are included below each part.

LABORATORY

A. Wastewater Characterization

At the Peyton packing plant, the effluent flows into a rectangular sedimentation-skimming tank (catch basin) which has a 30 minute detention time at peak flow. While the collection and distribution system was being designed and constructed, the wastewater from the catch basin was sampled and characterized. On six different occasions, samples were collected at one-half hour intervals for 24 hours from the effluent pipe of the catch basin. On two of these occasions influent samples were also taken. The depth of flow was measured in the effluent pipe and, using corresponding velocities as measured in a separate study, the total flow was calculated. In addition to analyzing the 48 one-half hour samples individually, a flow proportional composite sample was made and analyzed.

All samples were kept in a polystyrene cooler containing ice until they could be transported back to the laboratory, a storage time of approximately 3 hours. The samples were analyzed within 24 hours for pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Grease, Total Solids (TS), Volatile Total Solids (VTS), Suspended Solids (SS), Volatile Suspended Solids (VSS), and Total Kjeldahl Nitrogen (TKN). All tests were conducted according to the procedures specified in Standard Methods (8).

B. Grass Studies

In addition to the wastewater characterization study, a study was conducted to determine which type of soil cover should be planted in the application areas. Ideally, the grass selected for a soil treatment

system using meatpacking plant wastewater should possess the following characteristics: high salt tolerance, high moisture tolerance, long growing season, high nutrient uptake, and non-leguminous. While none of the common grasses that grow well in the Southwest possess all of the above mentioned qualities, there are several grasses which possess most of these qualities. These include- Bermuda (common or NK-27), Tall Wheat, Blue Panicum, and Tall Fescue. Bermuda and Blue Panicum are warm season grasses while Tall Wheat and Tall Fescue grow best during the cool season.

Laboratory studies were initiated to evaluate the acceptability of the grasses for the proposed irrigation conditions. The grasses were seeded in triplicate in one-gallon containers and irrigated two times per day at 0.9 and 1.8 cm per day. A similar set of controls was irrigated with plain tap water at the same rate and all containers were kept in a glass house without temperature or humidity controls.

After the laboratory studies were completed, those grasses which were found to be acceptable were planted in 2.5 x 2.5 m plots within each of the spray areas. These grasses were irrigated daily with tap water until germination, after which time they were irrigated with wastewater during the normal application periods.

FIELD

Two different types of land application systems were studied in this project, i.e., infiltration and overland flow. The infiltration studies were conducted using both high-pressure and low-pressure distribution systems. A description of each of the systems follows.

A. <u>High Pressure Infiltration System</u>

The initial system that was constructed on this project was a high pressure, sprinkler application, infiltration-type system. The wastewater was applied at 5.6 kgs/sq cm (80 spi) through Rainbird full circle sprinklers having a nozzle size of 1.35 cm. A single sprinkler head was used

in each of three areas which received wastewater at application rates of 6.3, 10, and 20/cm per week. Various application schedules were tested, ranging from one application per week to daily applications.

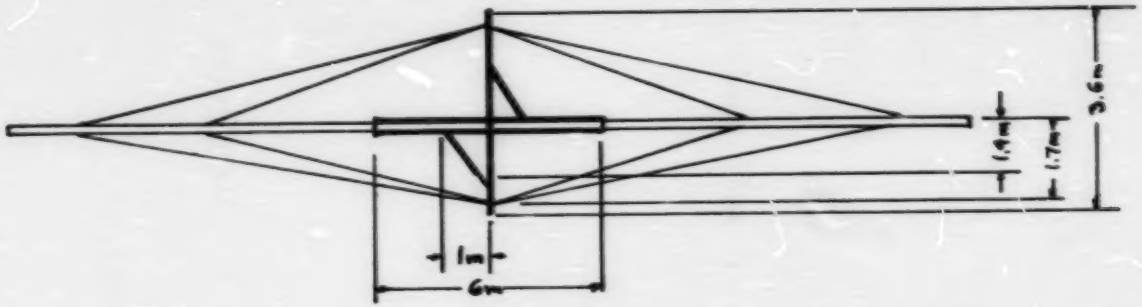
The distribution system was constructed of 10 cm and 15 cm aluminum pipes laid on the ground surface. Electric valves were installed on two of the lines in order to control the hydraulic loading rate. The volume applied to the third treatment area was controlled by turning the pump on and off with an electric clock.

Ceramic water samplers were installed at 30 cm intervals in each spray area so that the characteristics of the wastewater could be determined as a function of downward percolation distance. In addition 3.8 cm well point sampling wells were located around each spray area so that ground water samples could be collected and analyzed for chemical and bacteriological characteristics.

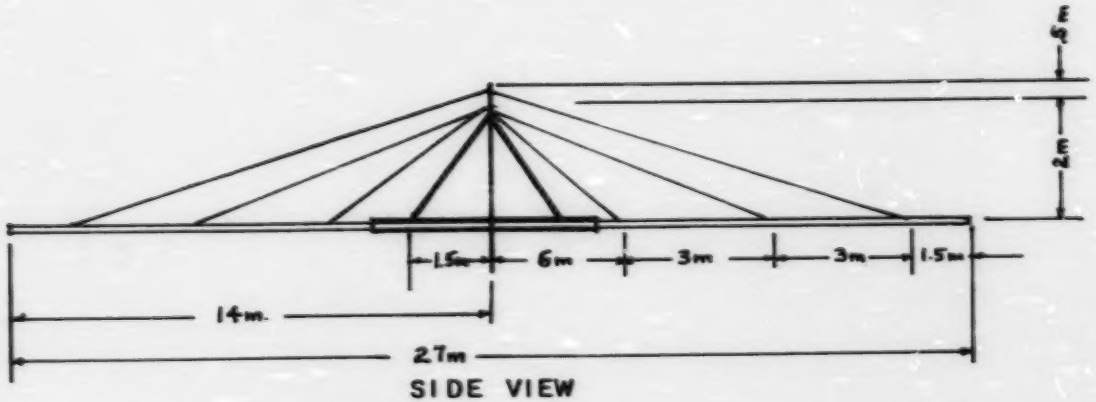
B. Low Pressure Infiltration System

A low pressure wastewater distribution system was deemed necessary after initial studies with the high-pressure system revealed that aerosol drift would present a significant problem. Therefore, a system was designed which had a very low initial investment cost and which was capable of operating at pressures as low as 0.4 kgs/sq cm (5 psi).

The low-pressure distribution system consisted of a central riser with two balanced arms on which Bete type FF nozzles were placed at various intervals. The arms were constructed primarily of EMT electrical conduit with a diameter of 28 meters. An extra 3 meters was gained by placing a nozzle turned outward at the end of each arm. At diameters greater than 28 meters it was not possible to properly balance and support the distributor arms with the inexpensive, lightweight materials that were used in their construction. Figure 1 shows an overall view of the distributor arms; and Figure 2 shows the details at the cross and the nozzle connections.



TOP VIEW



SIDE VIEW

Fig. 1. LOW PRESSURE DISTRIBUTOR

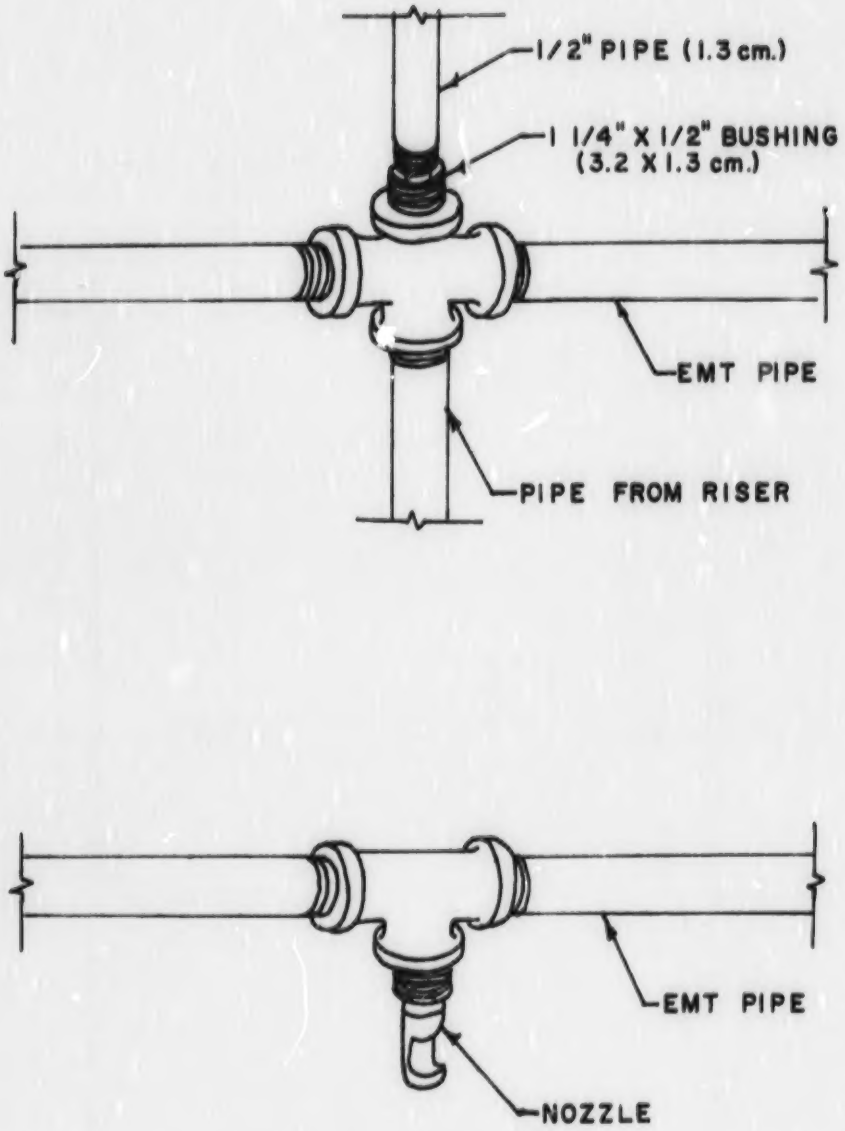


Fig. 2 DETAILS OF FITTINGS FOR DISTRIBUTOR

After the distributor arms were constructed, they were placed on the riser, which contained two bearings, a swivel, and various pieces of pipe. The details of the riser construction are shown in Figures 3 and 4. The riser was secured in place by pouring concrete around a three foot pipe section placed in the ground. The nozzles were 1.5 meters above the ground surface for easy access. The force caused by the wastewater flowing from the nozzles was sufficient to cause the distributor arm assembly to rotate about the riser support.

Overland Flow System

The overland flow system was constructed using the cut and fill method to achieve a 1 1/2% slope. The total area was 46 meters wide by 62 meters long. The rather shallow slope was mandated by the lack of availability of the more impervious clay-containing topsoil.

One half of the sloped area was seeded with Bermuda NK-37 and the other half with Kentucky Tall Fescue. The area was irrigated with tap water through high pressure sprinkler application until sufficient growth was established to avoid plant damage by the wastewater.

Wastewater application was accomplished via a low pressure, fixed distribution system. Bete fog nozzles were mounted on 1.9 m risers at 6.2 meter invervals along the top of the slope. Figure 5 is a schematic diagram of the distribution system.

The system was operated 6 hours per day at about 0.8 kgs/sq cm (12 psi) Monday through Friday, resulting in a hydraulic loading rate of 12.5 cm/week. Effluent wastewater was collected at the bottom of the runoff area in a 5 x 5 x 2 meter sump and pumped to an adjacent disposal area daily. Six 2.5 cm diameter galvanized pipes were installed just below the soil surface at approximately 9 meter intervals down the runoff area so that wastewater samples could be collected at various distances down the slope. Each pipe was 6.5 meters long with 1 cm holes drilled at 30 cm intervals. The pipes were buried and covered with gravel, with the end of each pipe protruding from the edge of the runoff area. Samples were

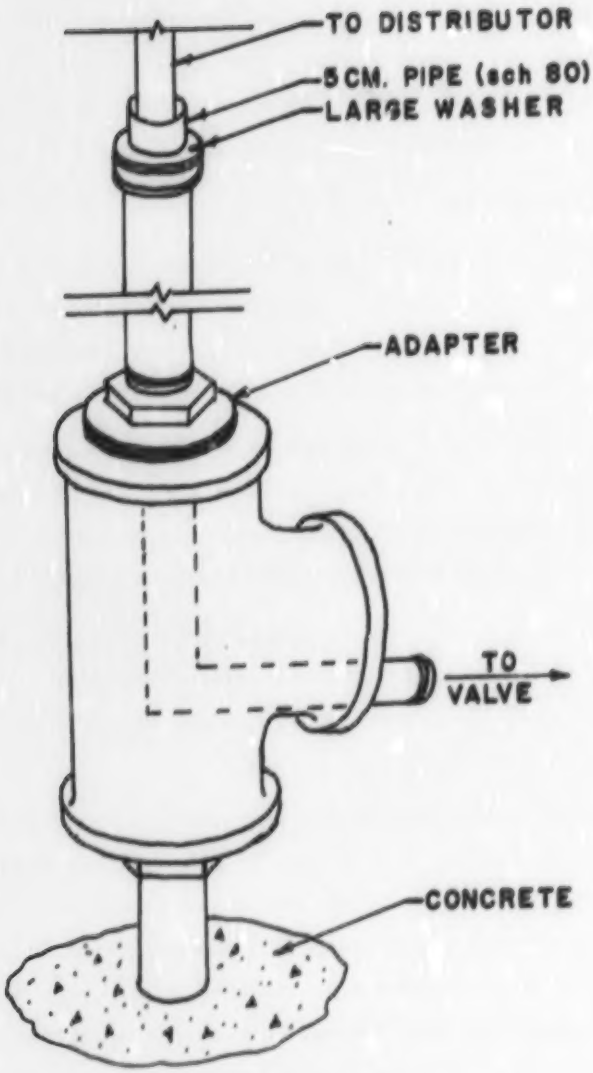


Fig.3 DISTRIBUTOR RISER
(See Fig 4 for exploded view)

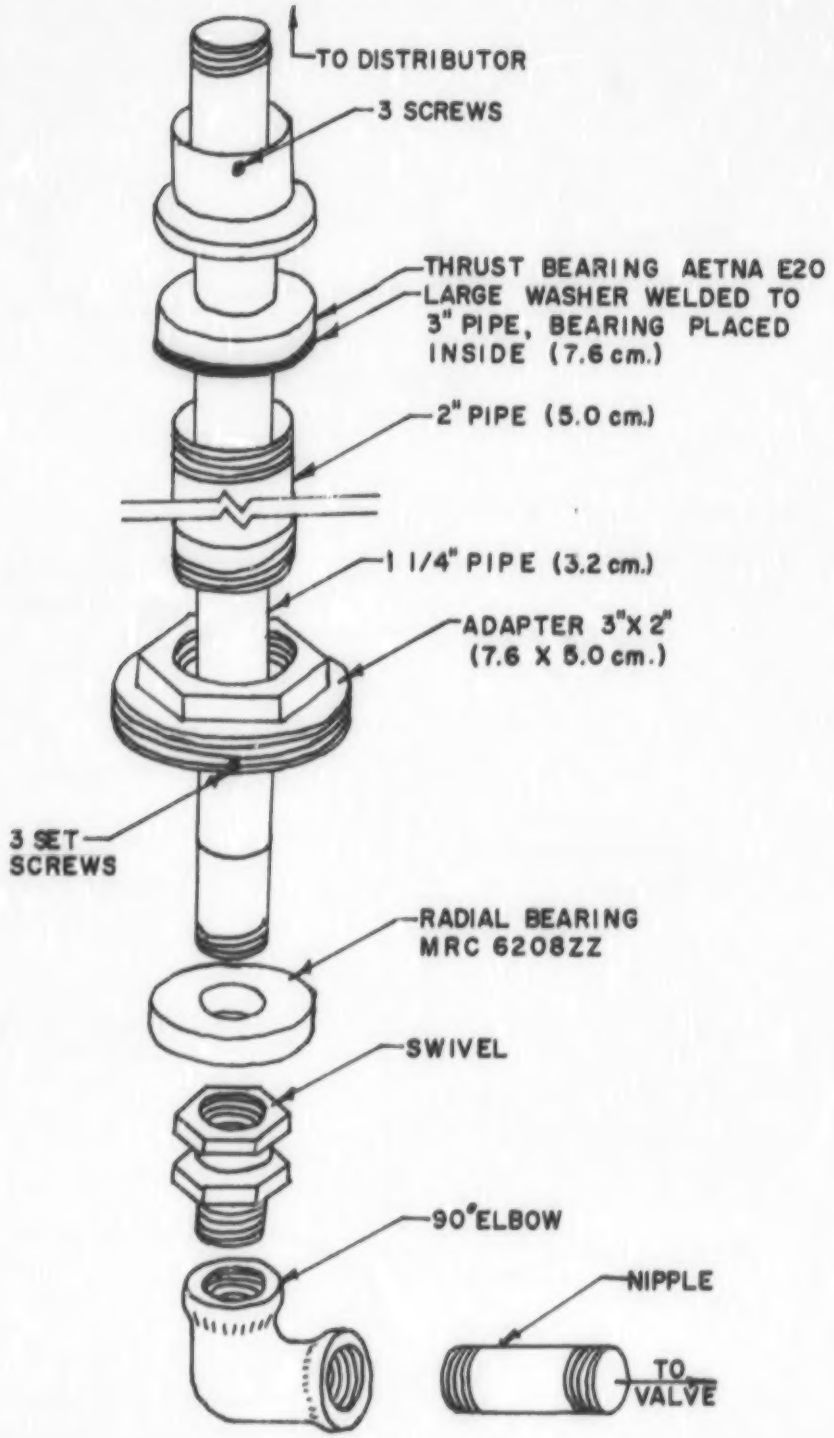
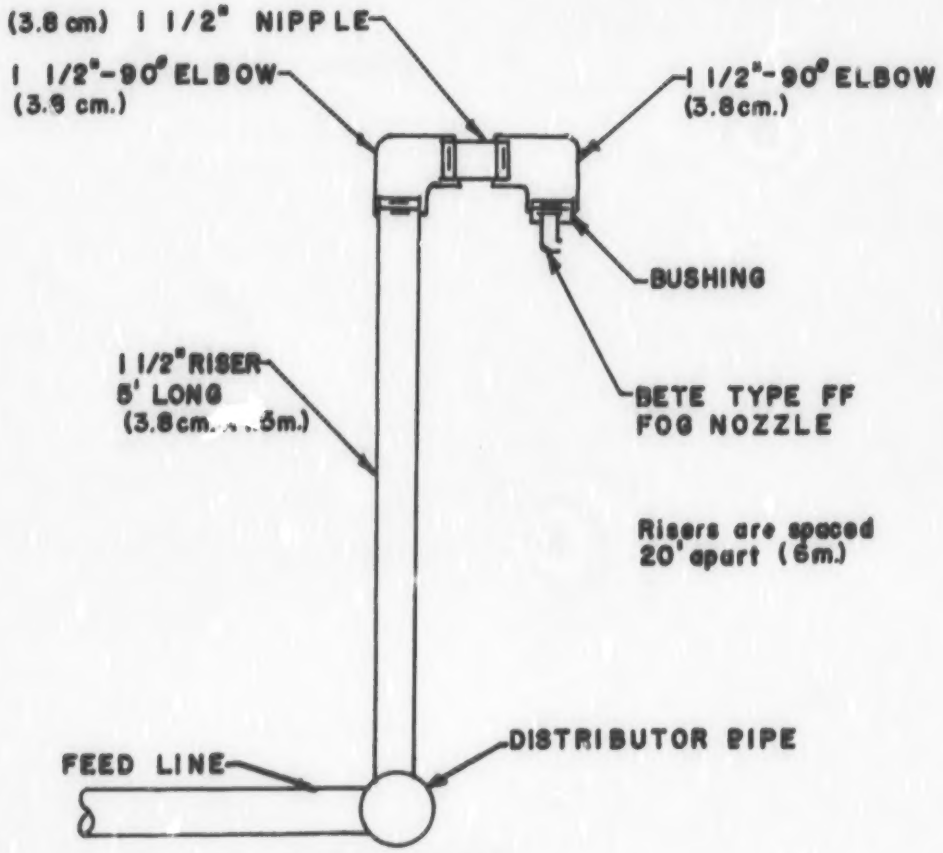


Fig. 4. DETAILS OF CONSTRUCTION OF THE RISER

FRONT VIEW



SIDE VIEW

Fig. 5 LOW PRESSURE RUNOFF AREA DISTRIBUTOR

collected by removing a cap from the end of the pipe and allowing the effluent to flow from the pipe for about 30 seconds so that representative samples could be obtained.

SECTION VI
RESULTS AND DISCUSSION

LABORATORY

A. Wastewater Characterization

In general, the strength of the wastewater as measured by the above tests was greatest during the killing hours of 6:30 a.m. and 3:30 p.m. The cleanup operations which began immediately after the killing stopped kept the wastewater strength fairly high until about midnight. Figure 6 shows the variation of BOD, COD, Grease and TKN versus time for one of the 24 hour analysis periods.

The graph shows that for meatpacking plant wastewater, the BOD and COD are directly related to the grease and TKN concentrations. From the data that was collected throughout the study, the COD:BOD ratio was found to be approximately 2.1:1. The COD:Grease ratio was found to be 2.95:1, which agrees well with the 2.99:1 value reported by McCarty, et al. (9). For whole blood, the COD:N ratio was found to be 11.9:1 while the BOD:N ratio was 9.2:1. The BOD:N ratio found here is a little lower than the 11.9:1 value reported by Fuller and Hill (10).

Table 2 shows the average results of some of the analysis performed on the effluent from the catch basin.

Table 2 - Catch Basin Effluent Characteristics

Parameter	Effluent Conc, mg/l ab	Range, mg/l
PH	7.3	6.6 - 8.1
BOD	2,600	200 - 15,150
COD	5,300	350 - 38,890
Grease	1,280	110 - 8,165
Phosphrous	17	3 - 35
Kjeldahl - N	110	19 - 680
Total solids	3,450	540 - 13,975
Suspended solids	1,600	15 - 10,350

a. Avg. obtained from flow proportional composite samples
b. Except pH

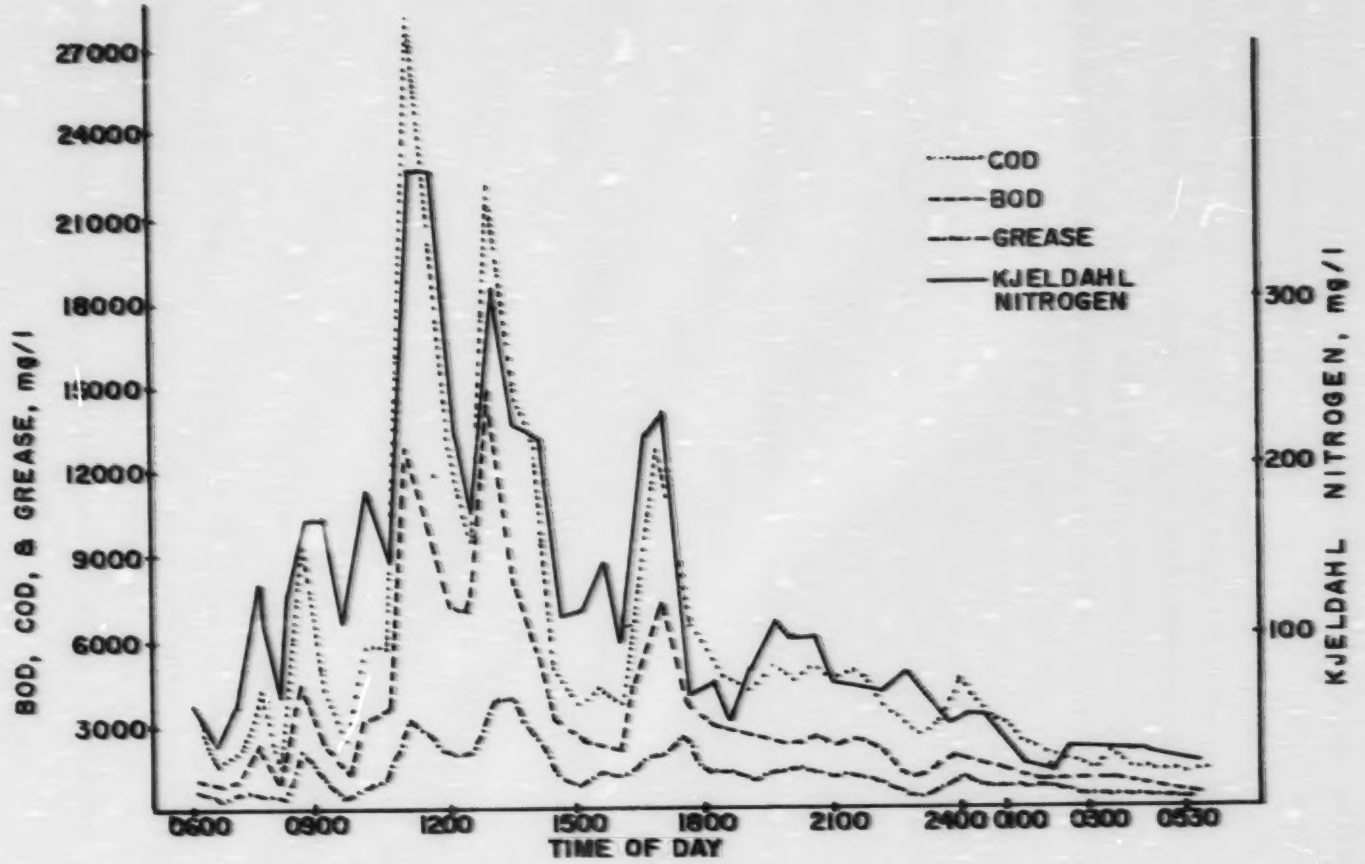


Fig. 6. VARIATION OF WASTEWATER STRENGTH WITH TIME

The most notable characteristics which contrast meatpacking plant wastewater from domestic wastewater are its high grease content, high nitrogen concentration, and extreme variations in short time intervals for all of the parameters shown in Table 2. The COD of the influent to the sedimentation tank has varied by as much as 100,000 mg/l between half-hour grab samples. Another distinguishing characteristic of the effluent from this plant was the presence of ground pieces of bone, some as large as 8 cm in diameter. These bone pieces necessitated screening in order to avoid pump damage and clogged nozzles during spray irrigation. The total flow during the initial part of the study was about 1.6 million liters per day or 3,560 liters per head. However, during the course of this study, in-plant changes were made which reduced the total flow to about 0.95 million liters per day and 2,080 liters per head. This reduced flow resulted in increased concentration for some of the wastewater parameters measured, particularly BOD and COD.

From the decrease in concentration between the influent and effluent for the parameters measured, the efficiency of the catch basin was calculated as shown in Table 3.

Table 3 - Catch Basin Efficiency

Parameter	Removal, %
BOD_5	60
COD	54
Grease	36
Total Solids	36
Volatile Total Solids	57
Suspended Solids	3
Volatile Suspended Solids	18

The BOD and COD removals were relatively good considering the type of treatment employed. The low percentage of grease removal in the catch basin was one of the major reasons for the high COD values of the effluent. The low removal of suspended solids was probably due to the fact

that the suspended solids test did not measure the grease as it flowed into the catch basin because it was hot and in liquid form. However, before reaching the effluent pipe, the grease had coagulated and was measured as suspended solids in the effluent.

B. Grass Studies

The initial results from the laboratory studies showed that most of the grasses which were irrigated with the meatpacking plant wastewater responded rather poorly. Inspection of the test containers revealed that some of the seeds and young shoots of grass were coated with grease and this condition apparently caused depressed germination of the grasses and inhibited growth.

A second test was started, therefore, in which all grasses were irrigated with plain tap water for the first two weeks in order to establish some growth before the effluent irrigation was begun. This procedure proved very satisfactory as all grasses grew at least as well as the grass in the control containers. No attempts were made to quantify the results since there appeared to be only slight differences between the test and control containers.

The laboratory results therefore, indicated that all of the grasses would grow well when irrigated with the wastewater, provided some growth had been established prior to application of the effluent.

The field tests which were conducted in 2.5 x 2.5 m plots confirmed the laboratory results, as all of the grasses grew very well in their respective growing season. The Tall Wheat, Tall Fescue, and Bermuda NK-37 were used in subsequent pilot scale studies as described later in the report. Of the grasses studied, Bermuda is particularly favored because it is a spreading grass which results in improved ground cover each year. The Bermuda also has a higher yield in the Southwestern U.S. than either of the cool-season grasses studied. Although Bermuda has approximately a six month dormant period in the Southwestern part of U.S., this did not appear to adversely affect the treatment efficiency of the system to a large degree.

FIELD

A. Infiltration System

The results reported below were obtained over an operating time of approximately one year. Table 4 shows the treatment efficiency of the system for the 6.3 cm and the 10 cm per week application rates as determined by the samples taken from the suction samplers at the 1.2 m level. It was evident from the outset that the soil could not accept the 20 cm/week application rate so this loading was discontinued. Application periods were approximately two hours in duration on Monday and Friday for the 6.3 cm/week rate and daily for the 10 cm rate.

Table 4 - Infiltration System Treatment Efficiency

	Percent Removal	
Parameter	6.3 cm/week	10 cm/week
Grease	100	100
COD	99	98
Nitrogen	72	58
SS	100	100

The average efficiency values shown in Table 4 were calculated from the wastewater values shown in Table 5,which represent the average strength of the wastewater that was applied to the treatment areas. These values are greater than the 24 hour average values shown in Table 2 because wastewater was applied only during daytime hours, at which time the wastewater strength was considerably higher than the average values.

Table 5 - Strength of Applied Wastewater

Parameter	Concentration, mg/l
BOD	5,800
COD	9,400
Grease	2,600
Total Kjeldahl Nitrogen	160
SS	3,140

The values reported were not corrected for evaporation so that the actual pounds removed could be somewhat greater than these calculated from this data. It should also be pointed out that the ceramic suction samplers would not allow suspended solids to be collected if any were present in the product wastewater. The data showed that suspended solids did not reach the first ceramic sampler located 30 cm below the soil. Furthermore, none of the samples collected from the well-point sampling wells at the three meter depth, which could collect suspended solids if any were present, ever contained a detectable amount of suspended matter.

As shown in Table 4, all of the grease was removed at both the 6.3 and 10 cm/week application rates. This is as expected, since most of the grease that was present in the wastewater was in the form of coagulated particles. The filtration of the grease by the soil was evident from visual observation of the soil surface after several weeks of wastewater application. However, after drying periods of one to two weeks duration, periodic soil analyses failed to show measurable amounts of grease in the surface soil samples (i.e., 0-2 cm) during the entire time this study was conducted.

The COD removal was excellent at both wastewater application rates studied, particularly in view of the extremely high organic loading rates employed. These rates were 2,214 kgs COD/ha/week at the 6.3 cm rate and 3,691 kgs COD/ha/week at the 10 cm rate. Figure 7 shows the COD removal as a function of downward percolation distance for both hydraulic loading rates. It is evident that most of the COD was removed within the first 30 cm of soil. There was, however, a wide range in COD removal rates, with some sample values as high as 980 mg/l. Nevertheless, these results show the excellent treatability of meatpacking plant wastewater by land application.

The high organic loading rates caused some problems with infiltration and odors, particularly at the higher loading rate. At approximately

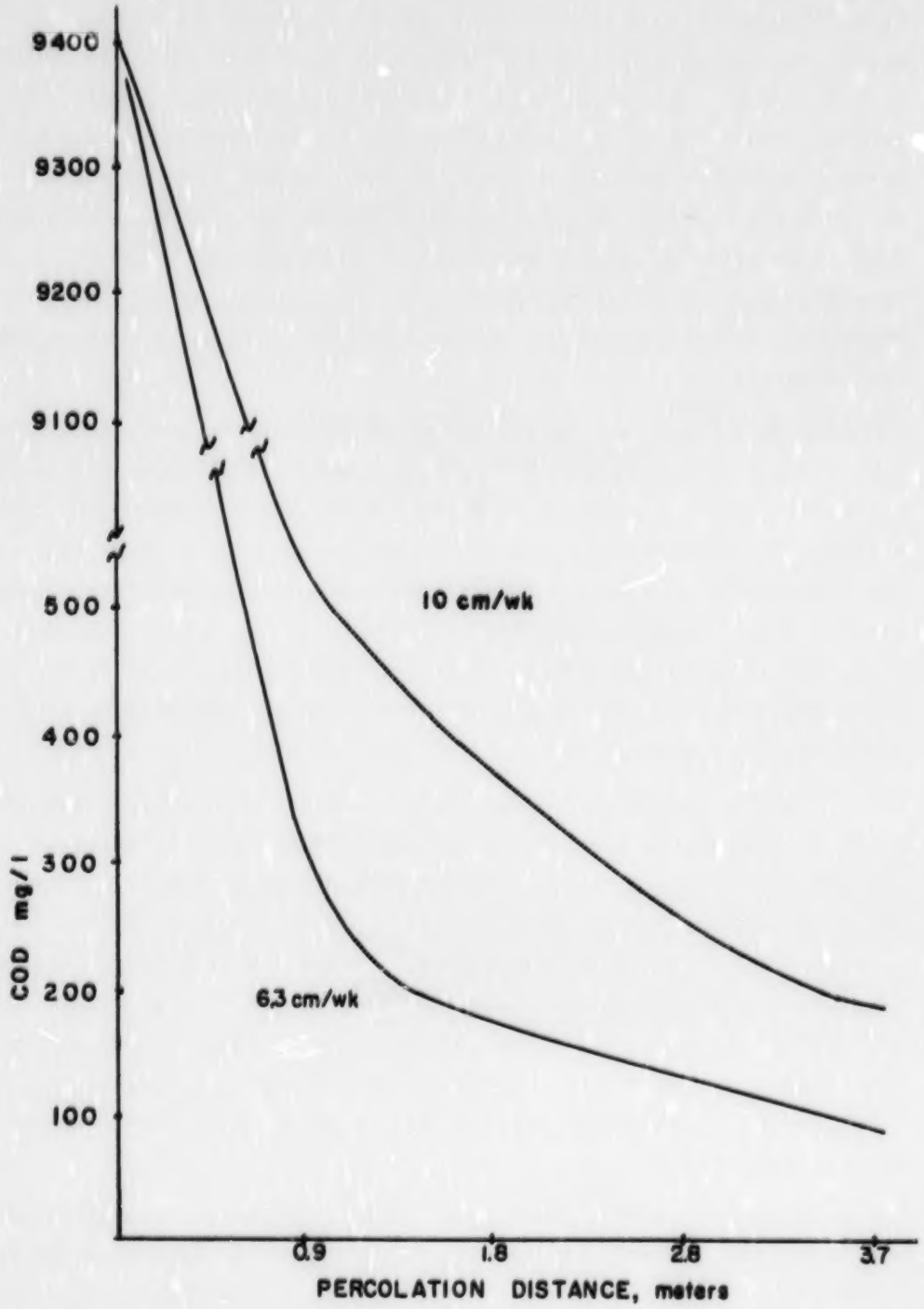


Fig. 7. COD REMOVAL VS PERCOLATION DISTANCE

three week intervals, it was necessary to omit one or more of the application periods in order to allow adequate drying time. If this were not done, the reduced infiltration rate would cause ponding with subsequent odor, and insect problems.

Nitrogen removal was also very good when the high loading rates were taken into account. The 6.3 cm/week hydraulic loading rate resulted in a 1,961 kgs N/ha/year loading while the nitrogen loading at the 10 cm/week rate was 3,267 kgs N/ha/year. Both values are much higher than the normal application rates recommended for agricultural fertilization. In terms of nitrogen removal 1,412 and 1,895 kgs/ha/year were removed at the 6.3 and 10 cm per week application rates respectively. The nitrogen removals obtained, therefore, obviously could not be accounted for in plant uptake alone.

Several mechanisms are involved in nitrogen removal during land application of wastewater, including denitrification and ion exchange (11). Filtration is also important for meatpacking plant wastewater because a considerable amount of nitrogen is present in the proteinaceous suspended solids emanating from the inedible rendering operations. Filtration of several wastewater samples revealed that approximately 50 percent of the Kjeldahl nitrogen could be removed by this mechanism alone. However, a nitrogen balance was not made so that the percent removal obtained by each mechanism is not known.

Well water analysis showed a gradual increase in nitrate concentrations through the study period at the 6.3 cm/week application rate. The nitrate level in well water samples under this area reached a high concentration of 4.1 mg/l from a background level of 0.1 mg/l. No similar increase was observed in the 10 cm/week application area, indicating that the higher organic loading rate may have caused more denitrification. Supporting evidence of this is the greater amount of nitrogen removed at the higher loading rate and the high concentrations of Kjeldahl nitrogen obtained in the suction samplers, with some values reaching 75 mg/l.

Figure 8 shows the Kjeldahl nitrogen concentrations in the soil for samples taken at the surface in each treatment area for the entire study period. As shown in the graph, the nitrogen concentration ranged from 0.1 mg N/g of soil to 5.1 mg N/g for the 10 cm/week application rate, with a slightly smaller range for the 6.3 cm/week rate. No consistent trend was evident at the surface in terms of nitrogen build-up. However, the peak concentrations observed in the June 15 samples were probably due to the fact that the treatment areas were plowed two days prior to that sampling. This indicates that there may have been higher nitrogen concentrations in the soil beneath the surface so that the relatively high nitrogen removals observed in this study could represent a short-term phenomenon.

Phosphorous removals varied so much throughout the study that average removal percentages would be relatively meaningless. That is, the initial suction samples showed that virtually all of the phosphorous had been removed from the treated wastewater at the 1.2 m level. However, these values increased rapidly so that very little phosphorous was removed in the treatment areas after the initial breakthrough. This observation is consistent with the theory that initial phosphate uptake is rapid according to the Langmuir or BET equation followed by a slower long term uptake which has been explained in terms of a reaction of the adsorbed phosphate with the substrate on which it has been adsorbed (12).

B. Overland Flow System

The data obtained in this part of the study were obtained over a period of approximately one and a half years. The first effluent samples which were taken from the runoff system in June indicated the COD removal efficiency was a little less than 50%. The low efficiency was expected because significant channeling was observed due to lack of complete ground cover. Furthermore, runoff-type treatment systems tend to improve with time for several years. By the middle of July, the grass in some parts of the runoff area was quite tall and in need of cutting. The area was

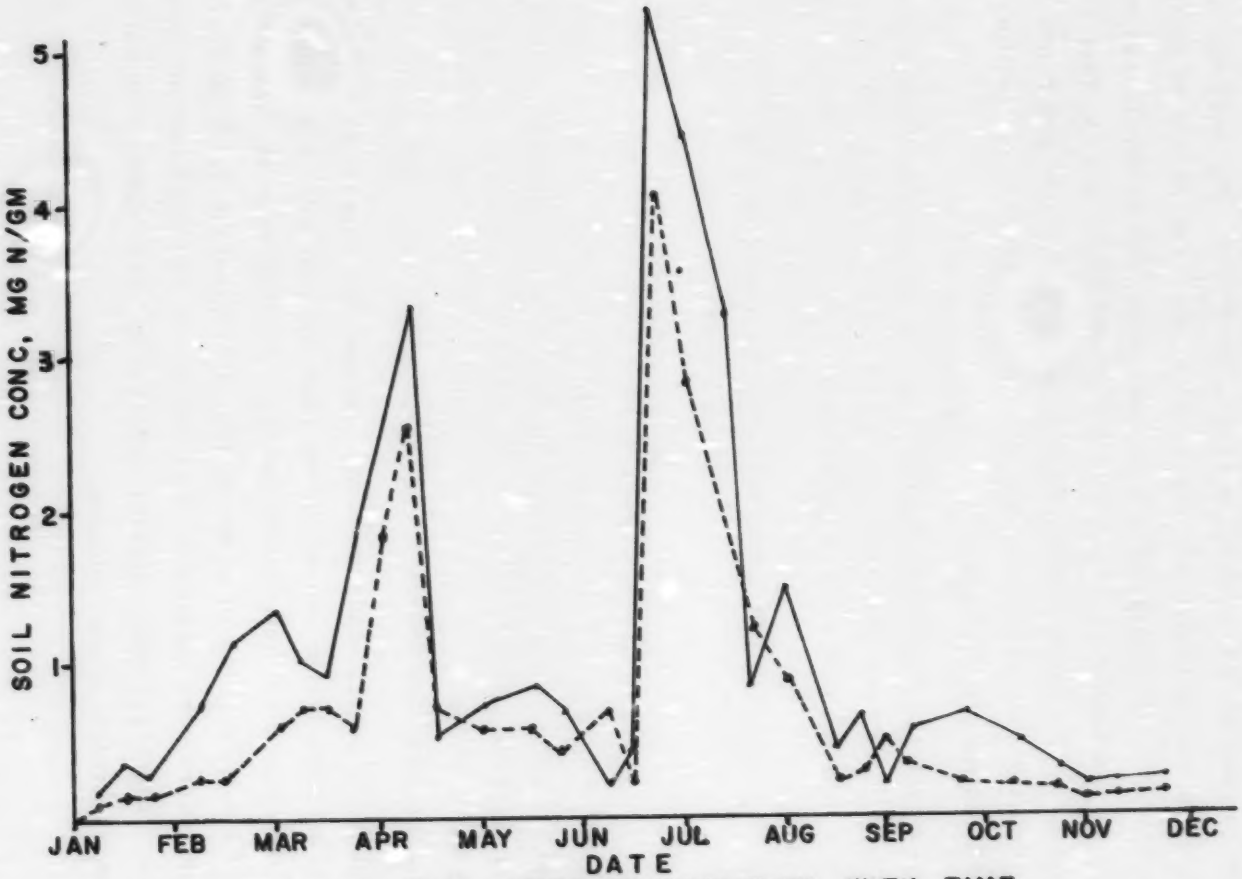


Fig. 8 SOIL KJELDAHL NITROGEN VARIATION WITH TIME

allowed to dry and the grasses were cut and baled, resulting in 32 bales weighing an average of 32 kgs per bale.

Wastewater application was restarted in early August and the efficiency of the system began to improve. By the end of September, the efficiency, with respect to COD removal, averaged about 66%. The area was again cut and baled and produced a yield of 67 bales. The increased yield was attributed to spreading of the Bermuda into some of the barren spots, but even at the second cutting about 10% of the field had not been covered. The bales which were collected were fed to the cattle which are kept in the holding pens overnight, and there was no apparent reluctance by the cattle to accept the hay.

The average treatment results obtained during the last nine months of the study are considered the most representative because of the "aging" of the system and are shown in Table 5.

Table 5 - Overland Flow Treatment Results

Parameter	Influent Conc, mg/l	Effluent Conc, mg/l	% Removal
COD	9,440	1,495	84
Kjeldahl Nitrogen	185	108	44
Total Solids	7,430	3,420	54
Volatile Total Solids	4,690	1,125	76
Suspended Solids	4,130	535	87
Volatile Suspended Solids	3,825	420	89

As with the infiltration treatment system, the overall efficiency of the overland flow system was excellent when the extremely high organic loading rate was taken into consideration. The COD removal, for example, was 2,017 kgs/ha/day, or in terms of BOD, approximately 1,009 kgs/ha/day. Slight odors were noticeable when the system was operated for more than three consecutive weeks without resting, but the odors disappeared quickly after applications were stopped.

Most of the nitrogen removal that was obtained was due to the nitrogen removed in the suspended solids. The effluent from the treatment area was usually reddish brown in color indicating that some blood was still present in the wastewater. Nitrates were never found in any of the effluent samples, probably because of the high organic loading rate. The total nitrogen removal was 104 kgs/ha/week, again more than could be accounted for by plant growth alone. Since no nitrates were present in the effluent, the nitrogen was either retained in the solids removed by the system, or lost through ammonia stripping or denitrification. As in the infiltration study, a nitrogen balance was not performed so the exact cause of the nitrogen removal is not known.

The solids data indicates relatively good system performance. The percent removals obtained for each of the solids parameters are consistent with the actual amount of volatile solids removed. That is, the difference between the influent and effluent concentrations for each parameter is close to 3,400 mg/l. This shows that only a very small amount of the dissolved (filterable) solids were removed. This is as expected since a large percentage of the dissolved solids were inorganic solids, particularly sodium chloride.

From the samples collected at the interceptor pipes located at approximately 9 meters down the runoff area, the efficiency of the treatment system with respect to travel distance down the slope was determined as shown in Figure 9. It is evident that the removal rate for each parameter decreased with travel distance down the slope, a phenomenon similar to the decreasing reaction rate in biological systems. Most of the organic materials were removed within the first 30 meters of the treatment area. However, it is apparent that by increasing the wastewater travel distance, a greater overall treatment efficiency could be achieved, particularly for COD. In designing an overland flow system for high strength meatpacking plants wastes, therefore, it appears that there would be some advantage to increasing the slope distance beyond 62 meters.

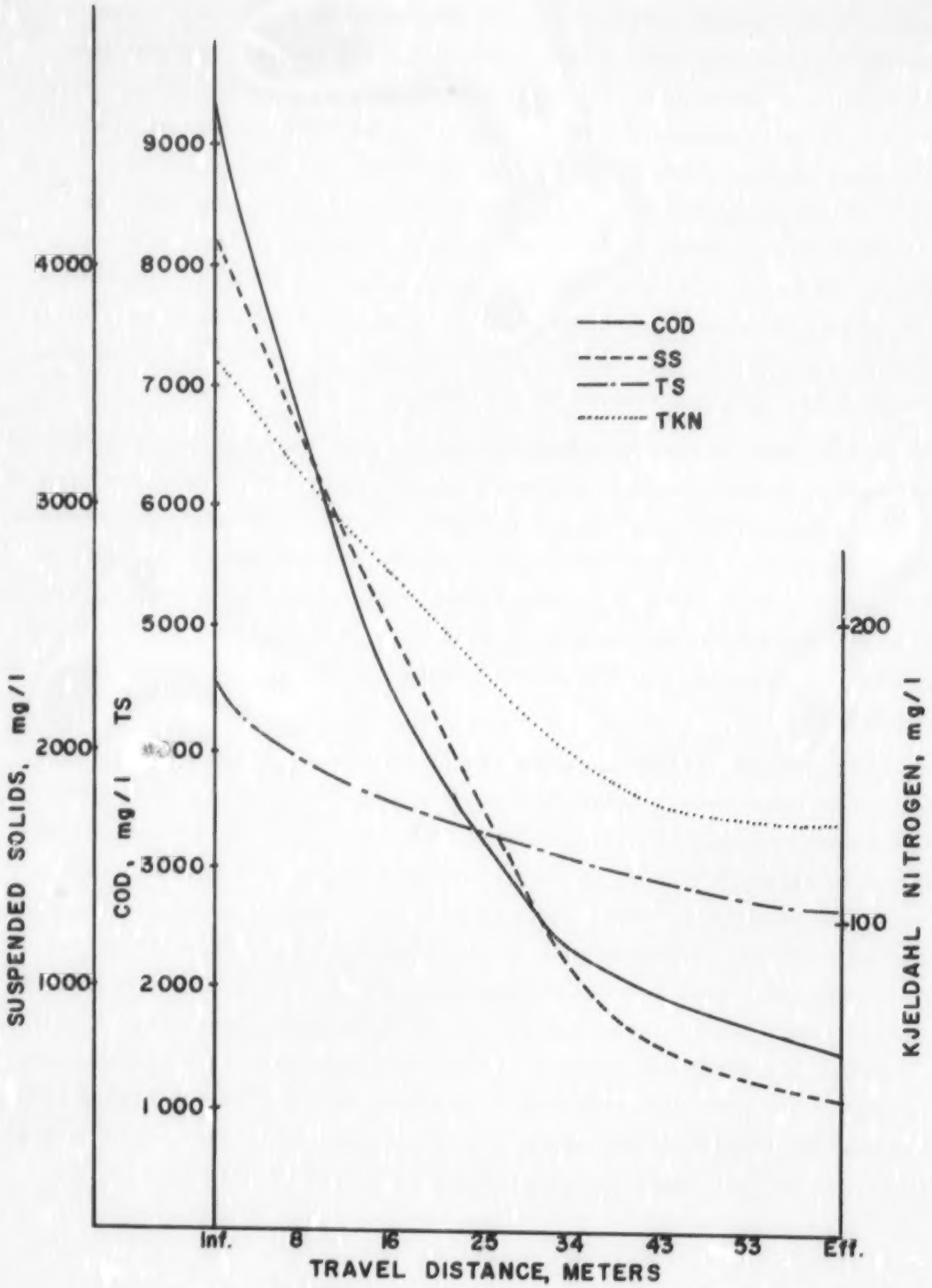


Fig. 9. TREATMENT EFFICENCY VS TRAVEL DISTANCE

Although there was a noticeable deposition of greasy looking solids at the edges of the sprinkler application area, these solids turned black and dried very well during resting periods. Utilization of proper operating and drying schedule, therefore, seems to eliminate any problems which might be caused by solids build-up.

On several occasions throughout the study, it was noted that the parameters which were used to measure treatment efficiency actually increased above the original concentration at the first and sometimes at the second interceptor pipe down the slope. This behavior is shown in Figure 10 for one of the 12-hour sampling periods and occurred when the system had been operated for an extended period of time without resting. Apparently suspended solids which had been previously removed within the first 9 meters of the treatment system were resuspended and carried further down the runoff area. After the treatment area was allowed to rest for about three or four days, however, treatment efficiency returned to normal. The interceptor pipes, therefore, in addition to providing information on treatment efficiency as a function of down-slope travel distance, provided a signal that the system should be rested before final effluent deterioration was observed.

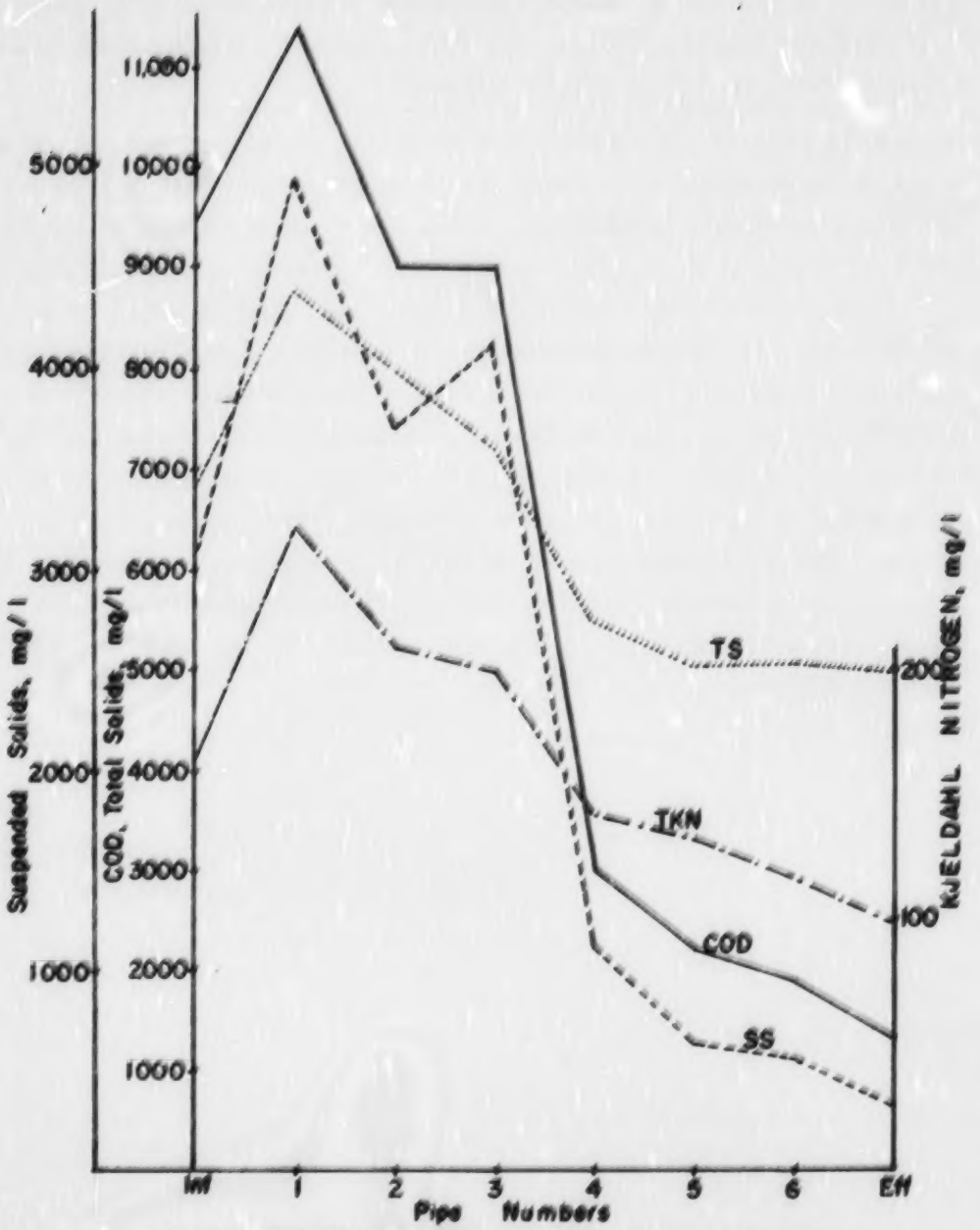


Fig. 10. TREATMENT RESULTS FOR ONE 12-HR RUN

SECTION VII

DISCUSSION OF RELATED THESES

During the conduct of the general land application feasibility studies, several theses and special reports were produced which dealt with specific aspects of the overall project. The results of some of these investigations are summarized below.

Because of the high strength of most meatpacking plant effluents and because of the varied operations inside the plant which generate wastewater, a study was undertaken with the objective of determining the quantity and quality of wastewater produced from the operations associated with the slaughtering and manufacturing process (13). Therefore, the sources of wastewater generation, both inside and ouside the plant were determined and various flow measurement and sampling schemes were established for each flow. The samples were then characterized by conducting the tests which were deemed most appropriate for that particular flow. The quantity and quality of flow from each unit source was expressed as a percentage of the total plant flow in order to determine if segregation of the wastewater from certain sources would be advisable.

Table 6 shows the percentage of the total flow which each source represents and the percentage of COD each contributed to the plant effluent COD. Thus the kill floor produced 44% of the total effluent flow but only 12% of the total COD. Similarly, the smokehouse flow contributed 16% to the flow but only less than 2% to the total COD. On the other hand, the rendering plant produced only 5% of the plant flow but represented 68% of the total plant COD.

When individual units are considered, the tripe washer produced only 1.8% of the flow, but 4.7% of the COD and 14 percent of the Kjeldahl nitrogen. Similarly, the blood holding tank produced less than 1% of the flow but accounted for nearly 12% of the Kjeldahl nitrogen. On the other hand, the automatic carcass washer produced over 17% of the flow with less than 5% of the COD.

Table 6 - Flow Rate and COD From Unit Processes

	SOURCE OF FLOW	FLOW GAL/MIN	FLOW GAL/DAY	% MEASURED FLOW	COD CONC. MG/L	% MEASURED COD
1)	Automatic Carcass Washer	75.0	40,500	17.3	4,360	4.9
2)	Manual Carcass Wash	8.8	4,752	2.0	-	-
3)	Carcass Grease Trough	11.9	6,426	2.7	1,598	0.3
4)	Tripe Washer	7.9	4,260	1.8	38,000	4.7
5)	Stomach Pipe	50.0	3,360	1.4	4,017	0.3
6)	Liver-Lung Table	4.6	2,484	1.1	620	-
7)	Chute Sprays	10.2	5,508	2.4	500**	0.1
8)	Entrails Wash	12.5	4,380	1.9	1,000**	0.1
9)	Beef Cheeks	6.9	4,122	1.8	603	0.1
10)	Cone Stomach Washer	12.0	783	0.3	1,000**	-
11)	Head Wash	15.2	2,337	1.0	6,712	0.5
12)	Tail Wash	8.6	748	0.3	233**	-
13)	Automatic Footwash	10.2	3,580	1.5	233	-
14)	Manual Footwash	9.4	1,574	0.7	233**	-
15)	Manual Foot Clean	2.5	1,080	0.5	233**	-
16)	Shroud Wash	25.0	3,000	1.3	2,290	0.2
17)	Evisceration Belt Sprays	15.0	8,100	3.5	300**	0.1
18)	Wash Basins	7.0	3,780	1.6	1,000**	0.1
19)	Misc Clean-up Hoses	10.0	1,080	0.5	1,000**	-
20)	Rear Corridor Hose	8.6	700	0.3	1,000**	-
	Kill Floor Subtotal		102,554	43.8		11.7
21)	Cure Injection Room	2.5	1,427	0.6	36,408	1.5
22)	Sausage Manufacture	10.0	2,000	0.0	2,000**	0.1
23)	Smokehouse	150.0	37,213	15.9	488	1.6
24)	Condenser Flow	10.8	7,761	3.3	1,240	0.3
25)	Blood Holding Tank	15.0	1,800	0.8	19,968	1.0
26)	Rendering-Grease Wash	10.0	2,329	1.0	987,000	66.8
	Rendering Plant Subtotal		11,890	5.1		68.1
27)	Cattle Pens	10.0	6,000	2.5	3,397	0.6
28)	Manure Screen Wash Water	11.2	3,360	1.4	51	-
29)	Clean-up Plantwide	95.5	69,453	29.7	8,178	16.2
30)	Blood Losses	20.0	20		330,720	0.2
	Total	162.4	233,917*			

* 85.2% of the average daily flow

** Estimated concentration

This study has shown very definitely the great differences in some of the unit flows. Furthermore, in some cases, segregation of the wastes from the main stream may be feasible.

In conjunction with the wastewater characterization by source study, a separate investigation was made to determine the treatability of certain unit wastes by chemical methods (14). Samples of dilute blood, tripe wash effluent and holding pen washwater were collected in addition to catch basin effluent and each was treated with various doses of ferric chloride and 1 mg/l of Nalco 676 polymer. Various coagulant aids were also tested but proved to be ineffective and were, therefore, not used in the final studies. The efficiency of the chemical treatment was determined by measuring the organic carbon and Kjeldahl nitrogen removals. The concentrations of blood were prepared in the range of 0.01% to 0.8% and treated with various concentrations of the coagulant and polymer. The results showed that carbon removal was linear with ferric chloride dosage, with slightly more than 4 mg/l of coagulant required for each mg/l of organic carbon removed. Thus, for the 0.8% blood solution, a coagulant dosage in excess of 2,500 mg/l was required in order to achieve greater than 90% reduction in organic carbon.

When similar tests were conducted on the tripe wash and manure samples, however, much lower concentrations of coagulant were required per unit of organic carbon removed. Thus, for the manure samples, there was approximately a 1:1 relationship between carbon removal and coagulant dosage. The tripe wash effluent was even easier to treat, with carbon removed to coagulant dosage ratio of approximately 2:1 for the higher carbon concentration ranges. For the catch basin effluent, the carbon removed to coagulant dosage ratio was found to be approximately 1:1.

The data obtained in this study indicate that there would be some advantage to mixing certain wastes together when chemical treatment is required. However, when chemical treatment is employed for recovery of marketable by-products such as blood, the advantage of the lower

chemical concentration required when wastes are mixed together may be offset by decreased quality of the desired by-product. The desirability of segregating some of the wastewater flows, for by-product recovery, therefore, would have to be determined on a case by case basis.

Since considerable aerosol drift was observed during high pressure application of the wastewater, a study was undertaken to determine the extent of the problem. This investigation included identification of some of the pathogenic microorganisms which were likely to be present in the packing plant effluent. Additionally, petrie dishes containing various culture media were placed at various distances both upwind and downwind from the high pressure and low pressure distribution nozzles. An Andersen Sampler and a Millipore Sterifil impinger were also used in this study, with M endo agar used in the Andersen sampler and Brain Heart Infusion broth in the liquid impinger.

Several types of pathogenic bacteria were isolated from the catch basin effluent. These included Staphlococcus, Streptococcus, Brucella, Salmonella, and Shigella. While various types of pathogens were found, isolation and identification of pathogens was difficult due to the fact that they are fastidious in their environmental requirements. No attempt was made to determine the percentage of time these pathogens would be present in the wastewater, but it appeared that very few could survive the temperature change, radiation exposure, and desiccation inherent in spray irrigation of the wastewater. Therefore, non pathogenic enteric organisms were used in the aerosol drift studies.

As expected, there was a considerable decrease in bacterial travel distance downwind with decreased operating pressure. Figure 11 shows a comparison of the enteric counts for the low pressure (1 kgs/sq cm) and the high pressure (5.6 kgs/sq cm) systems for wind speeds ranging from 10-16 kilometers per hour. Viable cells were transported approximately five times farther downwind with the high-pressure system. This could cause some difficulty if high pressure distribution systems were designed in

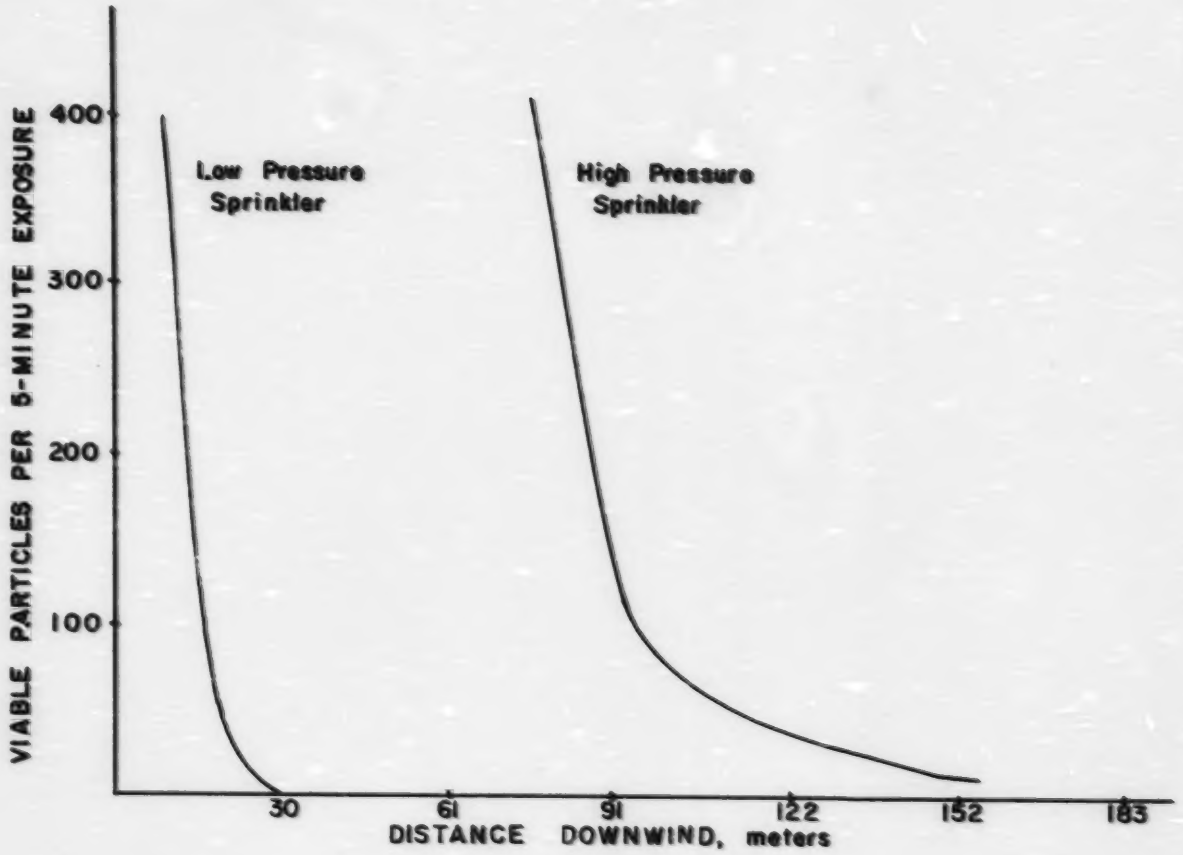


Fig. 11. VIABLE ENTERICS FROM AEROSOL DURING WIND OF 7-16 KPH

populated areas, particularly those localities where windy conditions are quite prevalent. The advantages of a low pressure system in this regard are obvious.

SECTION VIII

SUMMARY

The treatability of high strength meatpacking plant wastewater by land application has been shown to be excellent for both infiltration and overland flow type systems. With respect to organic carbon removal, both systems were shown to be very effective, achieving efficiencies of approximately 98% and 84% for the infiltration and overland flow systems respectively. The advantage of higher efficiency obtained with the infiltration system is offset somewhat by the more expensive and complicated distribution system involved. Additionally, recovery of the treated wastewater from an infiltration system would be more difficult if subsequent reuse were anticipated. There is also less likelihood of polluting potable water supplies with an overland flow system.

Nitrogen removal was also slightly better with the infiltration system than with overland flow. However, efficient nitrogen removal depends to a great extent on closely controlled operating conditions. The scope of this study was too wide ranging to study one aspect of system performance in detail, but it is felt that both types of systems can achieve much higher efficiencies than those found in this study.

The potential for phosphorous removal is obviously greater in an infiltration system than overland flow. Where phosphorous removal is of primary importance, therefore, infiltration systems offer a definite advantage compared to overland flow. On the other hand, when soil conditions are not favorable for phosphorous removal and chemical treatment must be employed, there are few considerations which would favor one system over the other.

POTENTIAL PROBLEMS

There are several potential problems associated with land application of meatpacking plant wastewater. One of these which requires immediate consideration is the possibility of the presence of pathogenic bacteria in the wastewater. Brucella, Steptococuss, Staphlococcus, Salmonella, and

Shigella bacteria have been isolated from the effluent of the catch basin on several occasions. The extent of this problem is not known at this time but should have a high priority in future studies or in proposed installations.

The problem of pathogenic bacteria present in the wastewater is compounded by the drifting of aerosols formed during application of the wastewater. Under even slight wind conditions (10-16 kilometers per hour) viable bacterial cells have been measured as far as 150 meters downwind for the high pressure system. For the low pressure distribution system, the maximum travel distance downwind was less than 30 meters. It is obvious, therefore, that this problem should be given careful consideration in designing a distribution system, with lower operating pressures preferred.

The high TDS concentration in most meatpacking plant wastewaters is caused by sodium chloride. As a result, most packing plant wastewaters have a very unfavorable sodium absorption ratio. This would cause serious problems with infiltration in clay-containing soils unless amendments were added. Sandy type soils are generally not affected by unfavorable sodium adsorption ratios and therefore are generally best suited for accepting meatpacking plant wastes as they leave the plant.

Finally, the high concentration of nitrogen present in most meatpacking plant wastewaters presents a potential problem of ground water pollution. The experience gained with soil treatment systems so far indicates that close control of the treatment system is required in order to remove greater than 50 percent of the nitrogen. Even then, the high concentration originally present could cause significant amounts of nitrogen to reach the ground water table.

SECTION IX

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